FOR DISCUSSION ONLY

HEATING HOMES WITH ELECTRICITY

A Study Made in Cooperation with
Warren Rural Electric Cooperative Corporation
Bowling Green, Kentucky

RURAL ELECTRIFICATION ADMINISTRATION
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C O N T E N T S

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INTRODUCTION

This study was initiated for the purpose of determining the effect of electric house heating on the capacity, demand, diversity and other characteristics of a rural distribution system. It should be considered as a case study, supplying a procedure or method of analyzing other systems, and therefore the figures as shown and the conclusions drawn therefrom may not apply to all situations.

The Warren Rural Electric Cooperative Corporation, Bowling Green, Kentucky made this study possible by supplying operating data on kilowatt-hours, demand, substation statistics and other details. From these were developed some of the technical and economic aspects of providing the necessary capacity to meet the system demand. Consideration was given to the following conditions which may exist on the system in 1959:

(a) No electric house heating.
(b) Five percent of the consumers having electric house heating.
(c) Ten percent of the consumers having electric house heating.
(d) Fifteen percent of the consumers having electric house heating.

The average connected load per house heating installation is estimated as 15 kw. This estimate agrees favorably with the actual installed capacity of 24 house heating consumers served by the cooperative. It includes 30 percent more capacity than indicated by the heat loss at zero F, the design temperature.

The average energy consumption per house heating member in 1959 is estimated at 450 kwh per month for all uses other than house heating. This figure is based on the records of 16 house heating consumers which indicates a consumption somewhat above the average for uses other than heating.

Note: The Rural Electrification Administration is especially grateful for the assistance given by Charles M. Stewart, Manager of the cooperative and members of his staff.

The energy consumption for non-house heating members is estimated at an average of 335 kwh per month by 1959. This was taken from the power requirements study developed in March 1949 by the Rural Electrification Administration. It is also assumed that by 1959 the system will be fully loaded and have no reserve capacity. The monthly kwh consumption for this group, from September 1949 through August 1950, is given in Table 1 as well as the projected kwh for 1959.

TABLE 1. DISTRIBUTION OF KWH, ACTUAL AND PROJECTED, FOR ALL CONSUMERS BY MONTHS USED FOR ALL PURPOSES OTHER THAN HOUSE HEATING

Month	Average kwh per member	Percent of average kwh	Estimated kwh, 1959
September 1949	150	96	322
October 1949	152	97	325
November 1949	158	101	338
December 1949	174	111	374
January 1950	168	108	362
February 1950	169	108	362
March 1950	151	97	325
April 1950	164	105	352
May 1950	156	100	335
June 1950	148	95	318
July 1950	136	87	292
August 1950	147	94	315
Totals	1,373		4,020

The average kwh per member, as shown in Table 1, were taken from the records of the borrower. The average for the year was 156 kwh which corresponded to the consumption during May. Taking this average as 100 percent, the monthly percentages were calculated, and the 1959 kwh were projected on the same basis.

ENERGY CONSUMPTION

As outlined previously it is estimated that by 1959 house heating consumers will use an average of 450 kwh monthly for purposes other than house heating and that non-house heating consumers will reach a monthly average of 335 kwh. The monthly distribution is shown in Table 1.

To determine the energy requirements for house heating it is necessary, among other things, to have data on the average, minimum temperature that may be expected and the number of degree days for a given area. In Table 2 both of these are shown by months for Bowling Green, Kentucky. The temperature data were obtained from the 25-year record of the United States Weather Bureau. The degree days were taken from the "Degree-Day Handbook" Second Edition, published by The Industrial Press, 148 Lafayette Street, New York, New York.

TABLE 2. AVERAGE DEGREE DAYS AND MINIMUM TEMPERATURE BY MONTHS FOR BOWLING GREEN, KY.

Month	Avg. Min. Temp. °F	Degree Days
January	7	865
February	11	767
March	19	496
April	31	219
May	41	-
June	50	-
July	-	-
August	-	-
September	45	-
October	33	161
November	20	510
December	11	837
Total		3,855

On the basis of 3,855 degree-days, and design temperatures of zero outside and 70 F inside the average annual energy consumption for heating each house will be 14,100 kwh. The following formula and data were used in this calculation:

$$F = \frac{\text{Connected load (Kw)} \times \text{Btu/kwh} \times \text{Degree Days}}{\text{Design temperature differential} \times \text{K (Constant)}}$$

$$= \frac{15 \times 3413 \times 3855}{70 \times 200}$$

$$= 14{,}100 \text{ kwh}$$

In this formula the constant "K" represents the average heat value of the fuel and the typical operating efficiency of the method of heating as shown in MPR Heating Bulletin, January 25, 1949, "Recommended Methods of Estimating the Annual Fuel Consumption and Fuel Cost for Heating Dwellings," Underwriting Division, Federal Housing Administration, Washington 25, D. C.

A breakdown by months in kwh for all uses by a house heating consumer is shown in Table 3.

TABLE 3. AVERAGE ESTIMATED MONTHLY ENERGY CONSUMPTION OF A CONSUMER HAVING ELECTRIC HOUSE HEATING

Month	Annual House Heating % of Kwh	Heating Kwh	All other Uses Kwh	Total Kwh
January	22.5	3172	491	3663
February	19.5	2750	491	3241
March	12.5	1763	453	2216
April	5.0	705	453	1158
May	1.2	169	453	622
June	-	-	414	414
July	-	-	414	414
August	-	-	414	414
September	0.8	113	442	555
October	4.0	564	442	1006
November	13.0	1833	442	2275
December	21.5	3031	491	3522
Totals	100.0	14,100	5,400	19,500

The percent of the kwh used for house heating for each month is the ratio of the number of degree days, Table 2, for each month to the annual total. The kwh per month for house heating were determined by applying the percentage for a given month as shown to the total, 14,100. The distribution of the estimated monthly energy consumption for all other uses is based on the percentages as shown in Table 1. except that identical usages per month have been assumed for each of the four seasons of the year. It should be

noted that the total energy consumption for the consumer who uses electricity for house heating approximates 19,500 kwh as compared to 4,020 kwh for the one who does not.

Attention is also called to the fact that of the 19,500 kwh used by the house heating consumer, 5,400 kwh were used for lighting and operating other electric equipment. On these bases the system requirements in kwh, both purchased and sold, for 1959 for no, 5, 10 and 15 percent of house heating are shown in Table 4. Distrubition system losses were estimated at 18 percent of the kwh purchased.

TABLE 4. SYSTEM KWH REQUIREMENTS FOR SEVERAL PERCENTAGES OF HOUSE HEATING FOR 1959

House Heating Saturation -%	System Kwh Purchased	System Kwh Sold
None	71,928,600	58,981,500
5	85,785,000	70,343,800
10	99,641,000	81,706,000
15	113,498,800	93,069,000

DEMAND, DIVERSITY AND LOAD FACTOR

Demand and diversity of electric equipment play an important part in the operation of an electric distribution system. As they vary, load factor, peak demand, capacity and other system characteristics may be changed so as to affect the economy of operation and possibly require alteration of the physical plant.

House Heating Consumers

The diversified kw demand for house heating only, per consumer, at the substation and its contribution to the peak periods is shown by months in Table 5.

TABLE 5. DIVERSIFIED KW DEMAND BY MONTHS FOR A HOUSE HEATING CONSUMER HAVING AN AVERAGE CONNECTED HEATING LOAD OF 15 KW

		Time of Day		
	Average	7:00 to	10:30 to	5:30 to
	Minimum	8:00 a.m.	11:30 a.m.	6:30 p.m.
Month	Temperature	Kw Demand	Kw Demand	Kw Demand
January	7	9.30	7.20	6.90
February	11	8.40	6.45	6.00
March	19	6.60	5.10	4.65
April	31	4.35	3.45	3.15
May	41	2.85	2.25	2.00
June	50	-	-	-
July	-	-	-	-
August	-	-	-	-
September	45	2.40	1.95	1.80
October	33	4.05	3.15	3.00
November	20	6.45	4.80	4.50
December	11	8.40	6.45	6.00

The kw demand figures shown in the previous table were determined from curves in Chart 1, "Heating Demand of House Heating Consumers as a Percent of Connected Heating Load for Various Outside Temperatures and Time of Day." For temperatures of 10 F and higher the curves of this chart were taken from "Economics of Distribution of Tennessee Valley Authority Power for House Heating" prepared by the Power Utilization Division, Tennessee Valley Authority, October, 1950. These were plotted from actual operating experience. The curves as shown for temperatures of less than 10 F were developed after reviewing weather records of the Weather Bureau, U. S. Department of Commerce, Washington, D. C. and other data. As stated in the "Introduction" the average house heating demand is based on an installed capacity of 15 kw. which is 30 percent greater than required at zero F, the design temperature.

It will be noted from both Chart 1 and Table 5 that the electric house heating demand is greatest from 7:00 to 8:00 a. m. in the month of January. During the entire heating season the morning heating demand exceeds that of both noon and evening, with the latter being the smallest.

Consideration must also be given to the kw demand and diversity of electric equipment other than that used for house heating as to its requirements and effect upon the distribution system.

TABLE 6. AVERAGE DIVERSIFIED NON-HEATING KW DEMAND BY MONTHS FOR A HOUSE HEATING CONSUMER

	Time of Day		
Month	7:00 to 8:00 a.m. Kw Demand	10:30 to 11:30 a.m. Kw Demand	5:30 to 6:30 p.m. Kw Demand
January	1.15	1.01	1.35
February	1.11	0.97	1.30
March	1.11	0.97	1.30
April	1.02	0.90	1.20
May	1.02	0.90	1.20
June	0.99	0.88	1.17
July	1.08	0.95	1.27
August	1.08	0.95	1.27
September	1.03	0.91	1.21
October	1.12	0.99	1.32
November	1.15	1.12	1.35
December	1.28	1.12	1.50

Table 6 shows the maximum average diversified kw demand for non-house heating loads at the substation per house heating consumer by months and for the same periods of the day as shown in Table 5. This was taken from REA Engineering Memorandum No. 94 R 5, "Maximum Demand at Substation," which shows a maximum demand of 1.5 kw for a consumer using 450 kwh per month. This occurs in December and varies by months as shown. This variation between months and between daily peak periods was calculated from actual demand records obtained from the borrower.

It should be noted that the kw demand for uses other than electric house heating is greatest during the evening, 5:30 to 6:30 p.m. This is contrary to the house heating demand which is greatest during the morning, but it should be remembered that the latter also does add to the evening demand. As house heating saturation increases with its high morning peak, the system peak will eventually change from evening to morning. Data as to when this happens follows on later pages.

TABLE 7. COMBINED AVERAGE DIVERSIFIED HEATING AND NON-HEATING KW DEMAND BY MONTHS FOR A HOUSE HEATING CONSUMER

Month	Average Minimum Temperature	Time of Day 7:00 to 8:00 a.m. Kw Demand	10:30 to 11:30 a.m. Kw Demand	5:30 to 6:30 p.m. Kw Demand
January	7	10.45	8.21	8.25
February	11	9.51	7.42	7.30
March	19	7.71	6.07	5.95
April	31	5.37	4.35	4.35
May	41	3.87	3.15	3.30
June	50	0.99	0.88	1.17
July	-	1.08	0.95	1.27
August	-	1.08	0.95	1.27
September	45	3.43	2.86	3.01
October	33	5.17	4.14	4.32
November	20	7.60	5.81	5.85
December	11	9.68	7.57	7.50

The combined heating and non-heating kw demand data as given in Table 7 are a summation of Tables 5 and 6. Chart 1 may also be used to determine the approximate kw demand for various connected electric house heating loads. For example, if the house has installed 20 kw of electric heaters, including a 30 percent reserve capacity, the maximum demand for the average minimum temperature of 7 F in January, from 7:00 to 8:00 a. m. is 20 x .62 or 12.4 kw. The kw demand for all other electric applications must be added to the 12.4 kw to get the total. For the 450 kwh per month consumer for January, 7:00 to 8:00 a. m. , the demand is 1.15 kw as shown in Table 6. The total heating and non-heating diversified demand is 12.4 plus 1.15 or 13.55 kw. The peak demand for different monthly kwh consumptions will vary and is available for demand tables. Kw demands for other months and average daily peak periods for the conditions as given in Tables 5 and 6 can be calculated.

Non-House Heating Consumers

By far the largest number of consumers will not be using electricity for heating. Their power requirements will have certain peaks and the combinations of equipment used bring about a definite diversity of use.

TABLE 8. AVERAGE DIVERSIFIED KW DEMAND BY MONTHS FOR A NON-HOUSE HEATING CONSUMER

	Time of Day		
Month	7:00 to 8:00 a.m. Kw Demand	10:30 to 11:30 a.m. Kw Demand	5:30 to 6.30 p.m. Kw Demand
January	0.86	0.76	1.01
February	0.83	0.78	0.97
March	0.83	0.78	0.97
April	0.77	0.68	0.90
May	0.77	0.68	0.90
June	0.74	0.65	0.87
July	0.81	0.71	0.95
August	0.81	0.71	0.95
September	0.77	0.68	0.91
October	0.84	0.74	0.99
November	0.86	0.76	1.01
December	0.95	0.84	1.12

Table 8 shows the maximum demand contribution at the substation for given periods of the day for each non-house heating consumer using 335 kwh per month. REA Engineering Memorandum No. 94 R 5 "Maximum Demand at Substation," shows the maximum demand to be 1.12 kw and this will occur in December with a monthly variation as shown. This variation between months and between daily peak periods was calculated from data obtained from the borrowers.

Kw Demand of Two Substations

Chart 2 shows the demand for two of the borrowers' substations, Bowling Green and Franklin, for two Mondays in January 1950. The residential consumers total 3348 for the two substations of which 1772 were served by Bowling Green and 1576 by Franklin. The evening peak demand in kw was 2300 for Bowling Green and 860 for Franklin substation, or a total of 3160 kw for both. The combined demand curve (3) as shown in Chart 2 was used to determine the consumer's demand as given in Tables 6 and 8, for both the morning and noon peak periods. The latter two were estimated to be approximately 85 and 75 percent of the evening peak respectively.

System Demand

The effects on the system demand of varying percentages of saturation of house heating that may be served in 1959 are shown in Table 9. These calculations are for 14,672 farm and non-farm residential consumers. The system demand used in this study for the house heating load was based on an outside temperature of 7 F, the average minimum that can be expected during January, the coldest month of the year.

TABLE 9. ESTIMATED SYSTEM DEMAND FOR ALL CONSUMERS IN 1959 INCLUDING SEVERAL HOUSE HEATING SATURATIONS FOR THREE TEMPERATURES

House Heating Saturation %	Temperature (F) 7	-2, Once in 3 Yrs.	-11, Once in 12 Yrs.
	System Demand-Kw		
None	16,433	16,433	16,433
5	21,116	21,747	23,509
10	26,755	29,995	33,448
15	33,734	38,579	43,864

It should be noted further, Table 9, that a temperature of -2 F may be expected on an average once in every three years and -11 F once in every 12 years. Corresponding system demands for these temperatures and for house heating saturations of 5, 10 and 15 percent are given in the same table.

Load Factor

Annual load factors of the system when having no, 5, 10 and 15 percent saturations of electric house heating are shown in Chart 3. With no house heating on the system the annual load factor is 41 percent. When house heating is considered by itself the annual load factor is only 17 percent. This is due to the fact that the equipment is not in use for about five months in the summer and only slightly during the late spring and early fall. This low percentage is reflected in a decrease of the system load factor as the saturation of house heating increases. For this system the load factor percentage drops from 41 to 38, 35 and 32 for saturations of 5, 10 and 15 percent of electric house heating.

PURCHASED POWER REQUIREMENTS AND COST

The wholesale power rate, TVA Schedule A, effective July 1, 1952 was used in calculating the power costs as estimated in this study. The rate schedule follows:

Demand charge -
Ninety cents per month per kilowatt of demand.
Energy charge -
First 100,000 kilowatt-hours consumed per month at 3.5 mills per kwh.
Next 200,000 kilowatt-hours consumed per month at 3.0 mills per kwh.
Next 700,000 kilowatt-hours consumed per month at 2.5 mills per kwh.
Excess over 1,000,000 kilowatt-hours consumed per month at 1.95 mills per kwh.

Determination of Demand

The demand for any month shall be the highest average load measured in kilowatts during any 60 consecutive minute period of the month, but, at TVA's option, when the power factor is found to be lower than 85 percent, the demand shall be 85 percent of the highest average kilovolt-amperes measured during any 60 consecutive minute period of the month.

Minimum Bill

The bill for power and energy for any month shall not be less than the demand charge for 60 percent of the highest demand during the previous 11 months.

Table 10 serves to illustrate the annual power requirements and wholesale power costs by months for Bowling Green Substation. A 10 percent saturation of house heating consumers or 276 of the 2757 is assumed.

TABLE 10. MONTHLY POWER REQUIREMENTS AND WHOLESALE POWER COSTS FOR BOWLING GREEN SUBSTATION ASSUMING A 10 PERCENT HOUSE HEATING SATURATION

	Jan.	Feb.	Mar.	April	May	June
Kw demand	5,018	4,684	4,187	3,434	3,144	2,481
Kwh bought	2,340,285	2,198,246	1,765,504	1,409,396	1,228,987	1,071,234
Kwh sold	1,919,034	1,802,562	1,447,713	1,155,705	1,007,769	878,412
Kw charge	$4,516	$4,216	$3,768	$3,091	$2,830	$2,233
Kwh charge	$5,314	$5,037	$4,193	$3,498	$3,147	$2,839
Power cost	$9,830	$9,253	$7,961	$6,589	$5,977	$5,072

	July	Aug.	Sept.	Oct.	Nov.	Dec.
Kw demand	2,707	2,707	3,088	3,648	4,231	5,029
Kwh bought	1,071,234	1,071,234	1,182,230	1,334,030	1,761,157	2,292,827
Kwh sold	878,412	878,412	969,429	1,093,905	1,444,149	1,880,118
Kw charge	$2,436	$2,436	$2,779	$3,283	$3,808	$4,526
Kwh charge	$2,839	$2,839	$3,055	$3,351	$4,184	$5,221
Power cost	$5,275	$5,275	$5,834	$6,634	$7,992	$9,747

The monthly peak diversified kw demands used in calculating the data for both house heating and non-house heating consumers are taken from Tables 7 and 8 respectively. For example, with a January demand of 10.45 kw each for the 276 house heating consumers the result is 2,884 kw and for the 2,481 non-house heating consumershaving an average demand of 0.86, 2134 kw. For both groups the total demand is 5,018 kw as shown in the table. In determining the electric energy sold, 3,663 kwh for the house heating consumers and 366 kwh for the others were applied to the number of consumers in each group for January respectively and then totaled. The same was done for all other months. Distribution system losses were estimated at 18 percent of the kwh purchased. TVA Schedule A was used in calculating the power costs.

SYSTEM INVESTMENT

When electric heating equipment is installed in a house, it is probable that the transformer and secondary service do not have the necessary capacity in kw to meet the added demand. Replacement may be necessary under such conditions.

Cost of Changing a Secondary Service

The cost for changing the secondary, including the transformer, as used in this study is $246.19. This was obtained from Middle Tennessee Electric Membership Corporation, Murfreesboro, Tennessee and is the average of 25 house heating installations. It is based on new material minus the salvage value of the old. The same holds for the transformers. Meters are the thermal demand type. The average demand of the installed heating equipment was 13.4 kw. A breakdown of the various costs follows:

Material	$37.56
Labor	28.49
Mileage	1.93
Transformer	129.86
	$197.84
Overhead 10%	19.78
	$217.62
Meter	37.57
	$255.19
Old meter salvage	9.00
	$246.19

System Improvements

As the saturation of electric house heating increases it becomes necessary to make system improvements to furnish the required capacity. Details as to the improvements and costs were furnished by the engineering staff of the cooperative. For a five percent saturation the total cost is $223,504; for 10 percent $873,455 and 15 percent $1,188,012. These do not include the cost of substations and transmission lines that would have to be built. It is estimated that $360,000 and $180,000 would have to be invested in new substations if 10 and 15 percent of the houses are heated electrically respectively. Ten miles of new transmission line, costing $100,000 would also have to be built to serve the 15 percent saturation. Required materials and costs for distribution facilities are listed in Table 11. It is assumed that TVA would supply the necessary transmission lines and substations. Therefore, these are not listed.

TABLE 11. SYSTEM IMPROVEMENTS AND COSTS NECESSARY TO SERVE THREE SATURATIONS OF ELECTRIC HOUSE HEATING

	House Heating Saturation -%					
	5		10		15	
Improvements	Miles	$	Miles	$	Miles	$
Bowling Green Substation						
1Ø #6 to 3Ø #6	1.31	1,800				
1Ø #6 to 3Ø #4	2.12	3,820				
1Ø #6 to 3Ø #2	2.00	4,300				
1Ø #6 to VØ #6	1.25	938				
1Ø #6 new	1.32	1,780				
VØ #6 to 3Ø #2	1.25	2,440				
Auburn Substation						
1Ø #6 to 3Ø #6	9.65	13,270				
1Ø #6 to VØ #6	6.75	5,812				
1Ø #6 new	6.5	8,780				
South Area						
1Ø #6 to 3Ø #6			29.72	40,865		
1Ø #6 to 3Ø #4			2.96	5,328		
1Ø #6 to 3Ø #2			5.35	11,502		
1Ø #6 to VØ #6			25.43	19,073		
1Ø #6 to VØ #4			0.8	1,440		
1Ø #6 new			21.15	28,498		
VØ #6 to 3Ø #6			2.07	1,035		
VØ #6 to 3Ø #2			0.3	535		
VØ #6 new			2.8	5,040		
VØ #4 new			1.7	3,400		
3Ø #6 to 3Ø #1/0			6.25	16,562		
3Ø #4 to 3Ø 1/C #4 D. C.			0.6	1,860		
3Ø #1/0 to 3Ø 1/0 #2 D.C.			0.76	2,052		
3Ø #1/0 to 3Ø #1/0 D.C.			2.0	7,000		
3Ø #6 new			2.22	4,662		
North Area						
1Ø #6 to 3Ø #6			50.5	70,800		
1Ø #6 to 3Ø #4			3.5	6,300		
1Ø #6 to 3Ø #2			18.5	39,905		
1Ø #6 to 3Ø #1/0			0.8	2,260		
1Ø #6 to VØ #6			44.6	35,205		
1Ø #6 new			17.7	23,545		
VØ #6 to 3Ø #6			5.0	2,955		
VØ #6 to 3Ø #2			4.8	9,355		
VØ #6 to 3Ø #2 D.C.			0.3	1,680		
VØ #6 new			8.5	15,300		
3Ø #6 new			7.5	15,330		
3Ø #2 new			13.0	35,100		

TABLE 11. (Continued)

Improvements	House Heating Saturation - % 5 Miles	5 $	10 Miles	10 $	15 Miles	15 $
Auburn Substation - Feder lines						
1Ø #6 to 3Ø #6			15.0	20,625		
1Ø #6 to VØ #6			12.0	9,000		
VØ #6 to 3Ø #6			15.0	7,500		
VØ #6 to 3Ø #4			5.0	8,250		
3Ø #6 to 3Ø #2			6.0	11,175		
3Ø #6 to 3Ø #4			4.0	6,200		
Scottsville Road Substation, Feeder lines, Sectionalizing, etc.						35,000
Caneyville Substation, Feeder lines, Sectionalizing, etc.						45,000
1Ø # 6 to 3Ø #6					2.0	2,760
VØ #6 to 3Ø #2					5.0	9,750
3Ø #6 to 3Ø #2					12.0	22,200
3Ø #6 to 3Ø # 1/0					1.0	2,650
3Ø #4 to 3Ø #2					1.75	2,888
3Ø #4 to 3Ø #1/0					3.0	7,350
3Ø #2 to 3Ø #1/0					3.5	6,405
Secondary-Services, Meters and Transformers		180,564		180,564		180,564
Totals		223,504		649,951		314,557
Cumulative Totals				873,455		1,188,012

ANNUAL EXPENDITURES

The incremental annual expense and debt service incident to the additional plant investment is shown in Table 12.

TABLE 12. INCREMENTAL ANNUAL EXPENDITURES AND REVENUES RESULTING FROM 5, 10 and 15 PERCENT HOUSE HEATING SERVICE

	House Heating Saturation - %		
	5	10	15
House heating consumers	734	1,468	2,202
Additional investment required	$223,504	$873,455	$1,188,012
Annual Expenditures			
Interest and amortization-4.5%	$10,058	$39,305	$53,460
Distribution, operation and maintenance-2%	4,470	17,469	23,760
Replacement-1%	2,235	8,734	11,880
Taxes and insurance-1/2%	1,118	4,367	5,940
Total added investment expense	$17,881	$69,875	$95,040
Added power cost	59,269	119,957	183,575
Total added expenditure	$77,150	$189,832	$278,615
Added revenue	77,129	154,238	231,367
Deficiency	$21	$35,594	$47,248

Based upon the terms of the REA loan, the interest and amortization payments are estimated at 4.5 percent of plant. This cost is shown in the previous table for 5, 10 and 15 percent house heating saturations as well as for a two percent allowance for distribution system maintenance and operation. The latter are based on actual data secured from many cooperatives. A one percent allowance is made for plant replacement. No depreciation expense is included because of the inclusion of the amortization item. One-half percent is allowed for taxes and insurance. The total incremental investment expenditure amounts to $17,881, $69,875 and $95,040 for 5, 10 and 15 percent saturations of electric house heating consumers respectively. It should be noted that in estimating these, no pro-rata share of other operating expenses such as consumer accounting and collecting, power use, general office salaries and administrative expenditures were included, although some increase is to be expected. In Table 13 the additional expenditures are prorated on a consumer basis and shown in mills

for each of the 15,480 kwh sold for house heating and the other uses over and above the 4020 kwh per year. Power costs, both total and per kwh, based upon demand and energy consumed are also shown.

TABLE 13. INCREMENTAL ANNUAL EXPENDITURES PER CONSUMER AND PER KWH SOLD FOR HOUSE HEATING CONSUMERS

	House Heating Saturation - %		
Annual Expenditures	5	10	15
Investment - expense per consumer	$24.40	$47.60	$43.10
Investment expense - mills/kwh	1.58	3.07	2.78
Power cost per consumer	$81.00	$81.60	$83.30
Power cost - mills/kwh	5.23	5.27	5.38
Total expenditures per consumer	$105.40	$129.20	$126.40

REVENUE

The residential rate schedule in effect and used to calculate the bills for both house heating and non-house heating consumers follows:

Residential Rate - TVA Schedule B-1

First	50	kwh	per	month	at	3.00	cents	per	kwh
Next	150	"	"	"	"	2.00	"	"	"
Next	200	"	"	"	"	1.00	"	"	"
Next	1,000	"	"	"	"	0.40	"	"	"
Excess over	1,400	"	"	"	"	0.75	"	"	"

Minimum Monthly Bill

$0.75 per meter

Amortization Charge

An amortization charge of one cent (1¢) per kwh for the first 100 kwh used per month, said charge to be not less than twnety-five cents ($0.25) nor more than one dollar ($1.00) per billing, per month, is added to all billings for electric energy.

The non-house heating consumer is expected to use an average of 335 kwh per month by 1959. The kwh usage per 100 consumers in each rate block, and the revenue derived therefrom, are shown in Table 14. The allocation of the number of kwh per block is based on REA experience tables which reflect the analysis of over 2,000,000 energy bills.

TABLE 14. ESTIMATED MONTHLY REVENUE FOR 100 NON-HOUSE HEATING CONSUMERS USING AN AVERAGE OF 335 KWH EACH

Rate Block Kwh	Usage Kwh	Rate per kwh ¢	Revenue $
50	4,800	4	192.00
50	3,900	3	117.00
100	5,300	2	106.00
200	7,200	1	72.00
1,000	11,200	0.4	44.80
Balance	1,100	0.75	8.25
Totals	33,500		540.05

It will be noted from Table 14 that the revenue received from 100 consumers using 335 kwh per month is $540.05 or $5.40 each. On a yearly basis this amounts to $64.80 each. The rates per kwh include the amortization charge which is part of the TVA Rate Schedule B-1.

The estimated monthly and annual revenue for house heating consumers is shown in Table 15.

TABLE 15. ESTIMATED REVENUE PER HOUSE HEATING CONSUMER BY MONTHS AND FOR THE YEAR

Month	Usage Kwh	Revenue $
January	3663	28.47
February	3241	25.31
March	2216	17.62
April	1159	10.53
May	484	6.51
June	484	6.51
July	484	6.51
August	484	6.51
September	484	6.51
October	1006	9.92
November	2275	18.06
December	3522	27.42
Totals for year	19,500	$169.88

The revenue for the months of May through September as shown in Table 15 was calculated from REA experience tables in a manner similar to that used in Table 14. In doing so, the average energy used per consumer during the five months was found from Table 3 to be 484 kwh. The revenue estimate for five months at this average usage will not differ appreciably from the revenue estimate arrived at by separate computations for each of the five months. The revenue for the other months, when electric house heating was employed, was determined by merely applying the residential retail rate, TVA Schedule B-1. to the kwh per month. This gives the correct revenue because the kwh usage of all house heating consumers is sufficiently large, during these months, to carry their usage into the final rate block.

The average annual revenue per residential non-house heating consumer is $64.80 as compared with $169.88 for the one who heats his house electrically. This is an increase in revenue of about $105 per year.

Comparing the total expenditures, Table 13, with the added revenue per consumer on an annual basis it will be noted that there is a deficiency under existing rates for each month of the three saturations of electric house heating. On the basis of five percent saturation where additional investment in distribution line is at a minimum and where there is no transmission investment, the revenue received barely covers the added expense. With any higher saturation, the distribution line investment increases considerably, resulting in a loss from heating service, even with the assumption that there will be no transmission expense and no increase in office or general expense.

SUMMARY

At the time these data were assembled the cooperative served 14,672 consumers. For analysis purposes, house heating consumer saturations of 5, 10 and 15 percent were considered or 734, 1,468 and 2,202 respectively. The average energy consumption for house heating is 14,100 kwh per consumer with a total of 19,500 kwh for all uses. The house heating consumer uses 5,400 kwh per year for other purposes as compared to 4,020 kwh for the one who does not employ it for heating. This is a total annual increase of 15,480 kwh.

Based upon TVA Schedule B-1, the existing residential rate, additional revenue in the amount of $105 is collected yearly from each house heating consumer. This is at an average of 6.79 mills per kwh. The total annual revenue is $169.88 as compared with $64.80 for the non-house heating consumer.

The maximum average morning demand for the 15 kw house heating load for the coldest month, January, is 9.3 kw. This is increased to 10.45 kw when the 5,400 kwh for other purposes are included. For the non-house heating consumer using only 4,200 kwh the maximum demand for this same period is 0.86 kw.

The annual load factor for house heating is 17 percent. For this distribution system the load factor is 41 percent without house heating. As electric house heating increases,the load factor decreases. At 15 percent saturation it is down to 32 percent.

A five percent saturation of house heating requires an additional system investment in primary distribution and service installations of $223,504; for 10 percent, $873,455; and for 15 percent, $1,188,012. The average added plant investments per house heating consumer are $305, $595 and $540 respectively. The additional investment in distribution plant is needed to provide the capacity over and above that required for the average overall farm and residential consumption of 335 kwh per month. No substation or transmission line investments are included as it is assumed that the power supplier will furnish these as needed. If these are no furnished, the cost to the cooperative for supplying electric power for house heating will be much higher than indicated.

The annual investment expenditures, plus the power costs per house heating consumer amount to $105.40, $129.20 and $126.40 for saturation of 5, 10 and 15 percent respectively. While the revenue approximates the costs for the five percent, it is considerably below for the higher saturations.

This report in no way should be or can be considered as a basis for determining the adequacy of the cooperative's farm and residential rate for usage other than house heating. It merely shows the effect of the large distribution capacity required for house heating loads and the resulting cost per kwh due to the seasonal nature and low annual load factor of house heating.

Even though the revenue under existing rates may be adequate for residential and farm use, it appears inadequate for electric house heating of this cooperative. It is apparent that there is sufficient surplus system capacity to take care of a low saturation of house heating. However, saturation which will require greatly increased plant capacity and investment will result in service at a loss.

GLOSSARY

Average Minimum Temperature - the average of all the monthly minimum temperatures for a station for a given month usually averaged for as many years as the station has records.

British Thermal Unit - the amount of heat necessary to raise the temperature of one pound of water one degree Fahrenheit. One kilowatt-hour of electricity will supply 3412 Btu.

Connected Load - the sum of the ratings of the electric power consuming apparatus connected to the system, or part of the system, under consideration.

Degree Day - a 24-hour period in which the average outside temperature is 1°F less than 65°F. The number of degree days per day is the difference between 65°F and the daily mean temperature when the latter is less than 65°F.

Example:

The highest temperature for a day was 70°F and the low 52°F.

Daily mean temperature $= \frac{70 + 52}{2} = 61°F$

Degree days for that day = 65 - 61 x 1 = 4

Demand - the load at the terminals of an installation or system averaged over a specified interval of time. Demand is expressed in kilowatts, kilovolt amperes or other suitable units.

Demand Factor - the ratio of the maximum demand of a system, or part of a system, to the total connected load of the system, or part of the system, under consideration.

Example:

A consumer has a total connected load of 20 kw and a maximum demand of 10 kw.

$$\text{Demand factor} = \frac{\text{Maximum demand}}{\text{Connected load}} = \frac{10}{20} \times 100 = 50 \text{ percent.}$$

Diversity Factor - the ratio of the sum of the individual maximum demands of the various subdivisions of a system, or part of a system, to the maximum demand of the whole system, or part under consideration.

Example:

Five consumers each having a maximum demand of 4 kw are served by one transformer. The total actual demand of all five is 10 kw.

$$\text{Diversity factor} = \frac{\text{Maximum total demand}}{\text{Actual total demand}} = \frac{4 \times 5}{10} = \frac{20}{10} = 2$$

Load Factor - the ratio of the average load over a designated period to the peak load occurring in that period.

Example:

A house heating consumer has a maximum demand of 10 kw during a one year period. The total energy consumed is 15,000 kw.

$$\begin{aligned}\text{Peak load} &= \text{Maximum demand} \times \text{No. of hours in year} \\ &= 10 \times 8760 \\ &= 87{,}600 \text{ kwh}\end{aligned}$$

$$\text{Annual load factor} = \frac{\text{Average load}}{\text{Peak load}} = \frac{15{,}000}{87{,}600} \times 100 = 17 \text{ percent}$$

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